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High Resolution Modeling of Naval Mine Countermeasures

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ABSTRACT

This report examines a modeling approach for naval mine countermeasures (MCM) in the very shallow water (VSW), surf zone (SZ) and beach zone (BZ). Clearing mines in this region of the battlefield poses serious problems to an amphibious landing force. Using an accredited U. S. Army model (Janus), modifications were made to the database creating amphibious systems and threat minefields. Three scenarios were developed representing an amphibious landing of a battalion-sized force using 1). no clearing; 2) traditional (current) MCM; and 3) a new technology (Lemmings). Data was collected from each scenario to investigate the ability of Janus to represent naval MCM at the battalion landing team level of interest.

1 Introduction

The recent Department of the Navy (DON) Mine Warfare Plan (MWP) [1] stresses the need to "Address the very shallow water, surf zone, and craft landing zone mine/obstacle countermeasures problems." The importance of this mission is magnified by the recent "From the Sea" doctrine of the DON and by the traditional role of Marine forces. The Mine Warfare Plan notes that effective Mine Countermeasures (MCM) in the craft landing zone (CLZ) is one of the "essential enabling elements of amphibious power-projection ashore operations" and the points out the importance of developing "MCM/EOD procedures and tactics to counter the threats."

2 Research Objective

We have two primary objectives in this research. The first, to build a meaningful base case scenario within a high-resolution combat simulation for investigating the total force effects of MCM system tactics in amphibious landings. The second, to demonstrate the usefulness of high-resolution combat simulation in the development and evaluation of such systems and tactics.

3 Background

The problem of Mine Countermeasures associated with amphibious operations is clearly a serious concern. In today's world, U.S. forces will be called upon to deal with various regional threats, each with unique obstacles to overcome. Since the collapse of the Soviet Union, the U.S. has been directly involved in at least five significant Lesser Regional Contingencies (LRCs) or conflicts (Persian Gulf War, Somalia, Haiti, Rwanda and now the Balkan crisis). Each of these LRCs either did involve or could have involved a naval mine threat, Rwanda excluded. Access to mines by Third World states is increasingly less difficult due to the huge inventory of Soviet mines in the newly independent former Soviet Republics. These states are in great need of cash and are quite willing to sell off their inventory of mines and other conventional weapons to generate such currency.

Mine warfare by its very nature is a significant threat. This threat is further complicated in the Very Swallow Water (VSW), Surf Zone (SZ) and Beach Zone (BZ). The density of mines and the difficulty of conducting amphibious operations in these zones make MCM that much harder. Add to this the requirement of "in stride" breaching and the difficulties of MW become clear. The SZ extends up to 350 yards from the beach along 75 percent of the world's coast lines . Many different mine types, such as bottom contact, influence, moored, antitank and antipersonnel mines are available to potential enemies and are easily laid by various means. Most mines can even be laid by hand in the SZ at low tide, thus accounting for the great mine densities in these zones. The "foam zone" the name given to the surf zone by Marine combat engineers, will continue to pose serious problems to the MCM efforts and future amphibious operations until more reliable solutions are adopted or developed by the Navy.

As new generations of MW/MCM equipment are entering the force, modeling represents an excellent tool for the development and evaluation of new tactics and procedures to maximize the effectiveness of this equipment. Of particular interest is a combat model that will capture the "in stride" tempo of the operation, modeling both sea and land maneuver with a seamless transition from water to land.

Previous research has demonstrated the ability of the Janus Combat Model to incorporate Naval and Marine Corps assets within an amphibious scenario. Janus is the Army's premier high resolution combat model used extensively since the mid seventies.

4 Amphibious Operations

4.1 Composition and Objective

An amphibious operation will be defined as an operation launched from the sea by naval and landing forces against a hostile or potentially hostile shore. There are four types of amphibious operations: amphibious assault; amphibious raid; amphibious demonstration; and amphibious withdrawal. Each type of operation is designed to achieve specific and different results. This research will focus on the amphibious assault. The amphibious assault differs from the other operations in that it involves establishing a force on a hostile shore. Once ashore, the goal of such a force is generally to: prosecute further combat operations; obtain a site for an advanced naval or air base; or deny the use of an area or facilities to the enemy. Given such critical goals, the amphibious operation is a complete operation within itself. It includes planning, embarkation of troops and equipment, rehearsals, movement to the objective area, final preparation of the objective, assault landing of troops and accompanying supplies and equipment, and continued support of the landing force (LF) until termination of the operation. Clearly, the success of such a complex operation requires intense coordination, clear communications, and thorough preparation and intelligence, among other things. Essential factors in the conduct of such an assault are flexibility of plans and speed in their execution.

The LF is comprised of a command headquarters and the combat, combat support, and combat service support units, with associated aviation assets needed to conduct the amphibious assault. The amphibious assault takes place within the assault area, which includes the beach area, the boat lanes, the lines of departure, the landing ship areas, the transport areas, and the fire support areas in the immediate vicinity of the boat lanes. The battalion landing team (BLT) is the basic task organization of the LF for the movement from ship to shore. The assault is initiated by the Assault Echelon (AE), composed of assault troops, landing craft, amphibious vehicles, helicopters, equipment, and supplies. The AE is launched from the line of departure, a designated line off-shore, approximately parallel to the landing beach. The AE's transit to the beach is conducted through boat lanes extending seaward from the landing beach to the line of departure. Each wave of the BLT, the first of which is in the AE, proceeds to designated landing zones as part of the total assault force effort at rapidly establishing a beachhead, a necessary requirement to expedite the landing of remaining troops and equipment. Establishment of the beachhead is the first major accomplishment toward meeting the ATF mission and completing the assault.

The objective of maneuver warfare is to collapse the enemy's will to fight. It seeks to shatter the enemy's cohesion through a series of rapid, violent, and unexpected actions, creating a turbulent and rapidly deteriorating situation with which the enemy cannot cope. This is accomplished by using tempo, speed, and surprise to apply strength against selected critical vulnerabilities of the enemy. Operational maneuver from the sea (OMFTS) is a blending of maneuver warfare with amphibious operations. Using the sea, air, and land as one maneuver space, the aim of OMFTS is to seamlessly project the Marine air-ground task force ashore striking decisively to destroy the enemys will to resist. OMFTS makes the presumption that ships at sea and Marines on land form a single, cohesive force, with no dividing line, either in time, space, or operational concept. As such, OMFTS can take full advantage of the extraordinary mobility offered by naval forces without loss of momentum during the ship-to-shore transition. Ideally, OMFTS offers an incredible opportunity to utilize our forces to their fullest extent while inflicting maximum damage on an enemy in a minimum of time. However, in practice, an OMFTS is subject to many variables, some of which are catastropic if unidentified and not appropriately dealt with in a timely manner. One such variable is mine warfare and the ever present threat of enemy mines.

5 Mines, Minefields, and the Enemy Threat

Many different mine capabilities are necessary to be able to conduct effective mine warfare. Consequently, there are many mine types and classifications, each designed to meet certain mine warfare requirements. Mines may be classified in several ways, for example as offensive or defensive, bottom or moored, contact or influence, as well as by size, type of influence, intended target, and method of delivery. Additionally, mines can be deployed in a wide range of depths, henceforth defined as follows:

- Deep water: greater than 200 feet
- Shallow water (SW): from 200 to 40 feet
- Very shallow water (VSW): from 40 to 10 feet
- Surf zone (SZ): from 10 feet to the high water mark (HWM)
- Beach zone (BZ): from the HWM inland (also called craft landing zone [CLZ])

A minefield (MF) is any collection of mines intentionally laid in some designated pattern or grouping intended to thwart the forward progress of an adversary. Minefields, like mines, may be classified as offensive or defensive. An offensive MF might be laid covertly in a foreign harbor or shipping channel, while a defensive MF might be laid along a coast line in order to prevent an attacking force from launching an amphibious landing. The composition of a MF might include one type of mine or a combination of several types, all designed to affect specific enemy forces in a particular manner.

6 Mine Countermeasures in Amphibious Operation

6.1 Background

The Mine Warfare Plan (MWP) [1] provides the framework for the requirements for an effective mine warfare force. Included is an assessment of the Navy's mine and MCM forces and capabilities in early 1992 and an outline of the strengths and weaknesses of those forces. Most importantly, the MWP discusses the Navy's mine warfare strategy for dealing with future threats and calls for a greater commitment to effective utilization of current mine warfare assets. It further emphasizes the need to identify and develop new mine warfare technologies to meet anticipated future threats. [1]

The MWP lists priority issues to be dealt with, one of which is an acknowledgment of the problems in conducting efficient, effective and speedy ("in stride") MCM operations in the VSW/SZ/BZ environments. Coupled with these priority issues are certain "critical initiatives and programs that we seek to emphasize in the coming years," one of which is the need to address the VSW/SZ/BZ mine/obstacle countermeasures problems. The MWP takes into account the need to: enhance our MCM capabilities for regional contingencies and independent operations, providing the people, training, systems, and forces upon which naval forces will rely in the future. Most fundamentally, the MWP reflects the enabling role mine warfare plays in our ability to control the seas and project military power into distant theaters, during peace time and war. [1]

6.2 Current MCM Capabilities in the VSW/SZ/BZ

"In stride" sweeping is a formidable task. It is estimated that today's MCM assets can clear mines in water depths as shallow as 10 to 15 feet. For shallower depths, however, there is currently no acceptably reliable procedure for breaching mines in the SZ/BZ. This means that during the critical phase of an amphibious landing, the transition from sea to land, there is no sure way to combat the mine threat for these zones utilizing in stride breaching, and thus preserve the advantages of speed and surprise. This poses a great threat to the LF. [2]

Of today's MCM forces, the assets which come closest to being able to provide "in stride" breaching are the MH-53E Sea Dragon helicopter towing the Mk 105 or Mk 106 Airborne Mine sweeping System, the SPU-1W Magnetic Orange Pipe (MOP), and the Marine Corps' Amphibious Assault Vehicle 7A1 (AAV) series outfitted with MCM equipment. The Mk 105 simulates the magnetic signatures of various ships and the Mk 106 simulates both magnetic and acoustic signatures, sweeping for magnetic and acoustic influence mines, and can be towed up to speeds of 25 knots with a magnetic sweep width of some 600 feet. The Mk 105 is rated to a minimum depth of 15 feet, however, when dealing with a real-world threat, the Mk 105 could be towed in as little as three feet of water. The Mk 105/106 hydrofoil sled has significant "combat" experience and has proven to be a highly effective MCM asset, having been used during Operation End Sweep in 1973 to sweep Haiphong's main shipping channel, to sweep the Suez Canal a year later, and most recently used in the Persian Gulf during Desert Shield/Storm. [3]

The MOP is a magnetized pipe 30 feet long filled with styrofoam for buoyancy that can be towed at speeds up to 15 knots three in tandem, thus offering a magnetic sweep width of some 90 feet. The MOP can be towed to much shallower depths than the Mk 105/106, but has a tendency to lose its magnetic charge and hence is not as reliable a breaching/clearing method. [2]

The Mk 105/106 and the MOP only counter the magnetic or acoustic mine threat and rely on helicopters, which are considered to be highly vulnerable in flight over the VSW/SZ/BZ regions. For this reason, it becomes necessary to equip AAVs or other landing craft with MCM to address the non-magnetic/non-acoustic mine threats in the SZ/BZ regions. The AAV can be equipped with the Mine Clearance System Kit, a modular line charge system which can be bolted to the cargo compartment. This is a modified M125 mine clearance system which uses a Mk22 rocket motor fired from an elevated launcher rail. The line charge has a 550 meter range, can clear 7m to either side of the line, and has an 80% clearance probability.[12]

These MCM assets come close to meeting the "in stride" requirement, but none were designed for such a mission and are not sufficiently reliable in the SZ/BZ environments. Of particular concern is the vulnerability of today's landing forces in the SZ region. Of all the current "in stride" MCM assets, none can effectively deal with mines in the SZ between the 10 foot and 5 foot depth curves. This critical area will be referred to as the "gap", and presently there are no MCM assets capable of dealing with it in a reliable manner.

The Navy is pursuing a number of SZ/BZ specific research and development (R&D) efforts to meet the "in stride" criteria and fill the "gap". One program, the precision emplacement of large explosive charges (PELEC), calls for the delivery by B-52s of 10,000-pound precision-guided bombs designed to penetrate to a depth of 21 feet into the bottom sediment and detonate within 0.01 seconds of each other to create a line-charge analog. Several versions of the PELEC are being researched. [4] Another R&D effort involves outfitting the LCAC with mine-breaching equipment. The so-called "MCAC" will fire M58 line charges or similar explosive systems into the SZ/BZ during breaching operations. [6] Several other R&D efforts are underway, all designed to counter the SZ/BZ mine threats. Unfortunately, none of these assets is fleet ready and certainly none have been tested with real-world threats. "The mine problem in the VSW/SZ/BZ is a special problem, and it requires nothing less than a special countermeasure." [4]

One proposed solution to the VSW/SZ/BZ is the Lemming swarming vehicle. Lemmings, developed by Foster-Miller, Inc. and currently undergoing field testing and analysis, were designed specifically to counter mines in the VSW/SZ/BZ utilizing a swarming approach to mine countermeasures. A "swarm" is defined to be a large group of Lemmings employed together to sweep for and neutralize mines. Lemmings are small (about 0.8 cu/ft per vehicle), tracked, bottom crawling, expendable mine hunter-killers which counter mines in the VSW/SZ/BZ by employing a quasi-random search pattern which provides a high probability of successful neutralization of mines in specified landing zones. They are adaptable to various delivery means (air, surface, subsurface) and can carry a wide variety of payloads, ranging from ordnance to surveillance. The cost per unit is very low and their advantages over traditional clearance/breaching methods are numerous, including covertness, limited risk to personnel, reliability, robustness, and "in stride" breaching capability both in the water and on the beach. A Lemming vehicle is pictured in Figure 1. Details of Lemming specifications, operating parameters, and swarm characteristics can be found in [5]. We will use Lemmings as an example of an advanced technology with potential to counter the mine threat in the VSW/SZ/BZ and compare any improvement to conventional MCM methods.

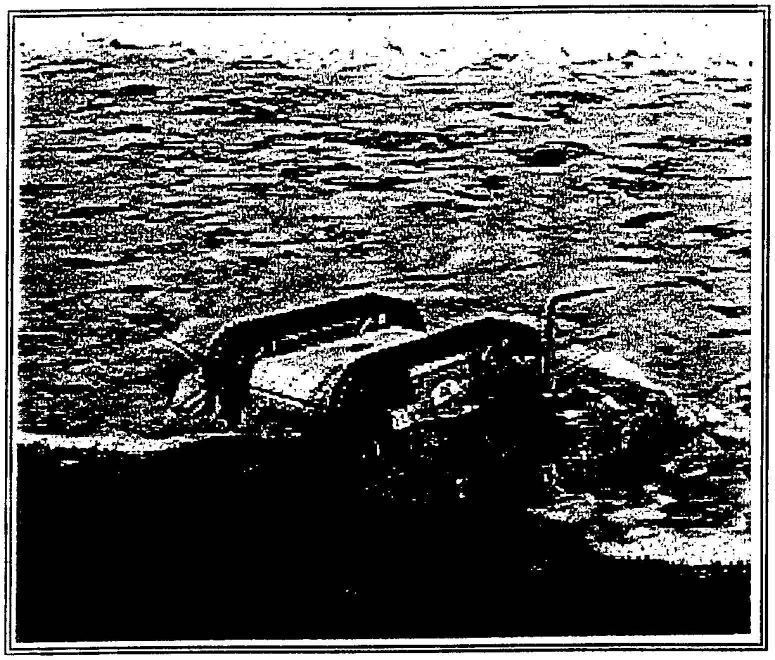

Figure 1. A Lemming Vehicle Detecting a Tilt-Rod Mine.

7 Mine Countermeasures Modeling

7.1 Characteristics of Janus

To properly model the MCM problem in the VSM/SZ/BZ for a battalion landing team, a high resolution simulation should be able to incorporate the interactions of the systems at the item level. Additionally, the simulation should provide a "seamless" transition between the land and sea. The Janus model has a robust database allowing the creation of amphibious systems and various terrain environments. This report examines the use of Janus to capture the unique MCM effects. A description of Janus follows.

Janus is an interactive wargaming simulation initially developed by the Lawrence Livermore National Laboratory in the mid-seventies. The Army has updated and revised the program to meet both combat development and training needs. The model is written in FORTRAN and has been adapted for use with the UNIX operating system in a desk top computer network. Janus(A), version 3.15, was used for this study.

Janus is a high resolution, interactive, two-sided, closed, stochastic, ground combat simulation. This high resolution model allows the user to create units as small as individual infantry and vehicular weapons systems. It then places these systems in ground combat scenarios with the focus on the maneuver of these systems either individually or as elements of larger units. The scenarios developed are two-sided, placing two forces, Blue and Red, in opposition to each other. The simulation is closed so that the disposition of one opposing force is unknown to the other until force locations are disclosed through direct observation or through intelligence reports generated by friendly forces. It is interactive because it allows the user to make changes in the scenario as events unfold without stopping the simulation. Finally, stochastic refers to the way the system determines the results of actions such as direct fire engagements or minefield crossing events: according to the laws of probability and chance. [6]

7.2 Major Features and Capabilities

The user runs simulations on digitized terrain maps developed for Janus from Defense Mapping Agency data. Each terrain map is a computer reproduction of actual terrain and is displayed in a military format using the Universal Transverse Mercator grid system. These terrain maps realistically model terrain contour, roads, vegetation, water and other obstacles. Janus also simulates the effects of light and weather. These factors all affect system movement, visibility, and target acquisition and must be considered when planning a scenario. [6]

The user plans the scenario and controls the battle with a simple mouse-driven user interface. The user may task organize units and place them in defensive positions or put them in an offensive posture. Units may be in full defilade, partial defilade, or put in prepared fighting positions. The user may designate movement routes from one position to another and plan movement starts and stops at specific times in the scenario. These routes and times may be altered at any time in the scenario before execution. Units on the move are in an exposed status but automatically go into partial defilade after stopping. Any weapons systems, whether on the move or stationary, may be placed in hold fire status. This capability allows the user to plan and direct fire on command. [6]

The user may designate some vehicles as troop carriers and mount or dismount them on command. The user may create minefields and simulate other man-made obstacles such as abatis, ditches and craters. Engineer vehicles may be equipped to breach and clear these minefields and obstacles. The user may also create artillery and mortar systems and plan indirect fire missions. Other systems may be designated as smoke generators that may be used to simulate the obscuration effects of smoke on the battlefield. [6]

The capabilities and features mentioned are just a few of those available to the user. Janus has an extensive and detailed database which the user can use to model systems and scenarios. The Janus developmental database has three major sections: combat systems, terrain maps and symbols, and testing and analysis. The combat systems database is the portion in which the user creates new systems and alters existing ones. In the terrain and symbols database, the user can edit terrain maps, create and alter system graphic symbols, and create map overlays for use in wargaming. For testing and analysis, the user puts systems and terrain into a scenario in which the systems and associated tactics can be tested. The user can then collect and analyze data through the post-processor to measure the effects of changes in systems and tactics.

7.3 Using Janus to Meet Research Objectives

By using Janus, we intend to create the necessary amphibious systems and have them interact with a modeled mine threat. Further, the ability of Janus to portray this interaction in various scenarios will be examined. Using the Janus Post Processor, data from these scenario runs will be analyzed to see if meaningful results can be obtained by using standard measures of effectiveness.

7.4 Advantages of Using Janus

In order to meet the research objective, three scenarios were developed in Janus, each identically modeled except for differences in MCM method employed. Janus offers an advantage of being able to create (simulate) identical environments in multiple scenarios through which comparative analysis can be performed. The environments created can be altered between scenarios as much or as little as desired in order to measure the effects of such changes on the model. The real utility of simulation lies in the ability to analyze and make predictions about new systems and tactics through the comparison of such alternative scenarios prior to actually developing or testing real-world systems and tactics. Indications about a system's potential can be realized through simulation modeling, and as such, help shape the path that R&D of that system takes.

Janus offers the advantage of being able to both evaluate a system's operational aspects (characteristics and performance capabilities) and a system's functional aspects (specifications). The operational aspects of Janus are realized during scenario execution and post-processing data analysis, while functional aspects are realized through database user inputs. A system's functional aspects directly affect that system's operational aspects. For instance, the modeling of a system, such as a Landing Craft Air Cushioned (LCAC), takes place in the database (functional), while its performance and effect on various aspects of a scenario (operational) are evaluated during scenario execution and post-processing.

7.5 Scenarios of Interest

The scenarios developed to meet the research objective are:

- Bull Breaching: an amphibious landing through a minefield in the VSW/SZ/BZ with no breaching operations.

- Traditional: an amphibious landing through a minefield in the VSW/SZ/BZ with current (today's technology) MCM assets being used for breaching.

- Lemmings: an amphibious landing through a minefield in the VSW/SZ/BZ utilizing Lemming swarms as the breaching method.

In developing these scenarios, crucial assumptions were made concerning several aspects of the assault. These assumptions will be discussed in Section 9.

8 Model Development

8.1 Janus Combat Systens Database

This section describes how indiviudal systems used in this study were represented within the Janus database.

It is within the Combat Systems Database (CS) that each individual system (e.g., LCAC, AAV, MH-53E, etc.) is created, edited, and maintained. Database inputs include such system characteristics as dimensions, weight, carrying capacity, and speed. Additionally, weapon and sensor types and capabilities can be incorporated into the database.

Mine types and minefield classifications are also defined by the user within the CS Data Base, as are each system's vulnerabilities to each mine type. The assignment of a breaching capability to an individual system is made within the Force Definition file of Janus. However, the effectiveness of each breaching method (e.g., plow, roller, line charge) is assigned within the CS Database. In addition to breaching method effectiveness, each method is also assigned a survival probability specifying the likelihood that an MCM system will survive given that it has encountered a mine. For example, a mine breaching plow attached to a tank may be assigned an 80 percent chance of successfully neutralizing a certain mine type (method effectiveness), but only a 75 percent chance of surviving given that it encountered that same mine (method survivability).

Each system which is created within the CS Database is also assigned certain probabilities relating to mine encounters. For instance, an LCAC might be assigned an 85 percent chance of activating a magnetic mine if it passes over it and, if mine activation occurs, only a 40 percent chance of actually being killed by that mine. Each system is assigned different mine activation and mine kill probabilities for each type of mine being modeled within a given scenario (e.g., magnetic, anti-tank, bottom contact, etc.). System vulnerability probabilities to mines and breaching method effectiveness probabilities specific to this research are outlined in Appendix A.

8.2 Assumptions and System Development

This report makes the assumption that the LF will be launched from the ATF over-the-horizon (OTH) at approximately 20 nm off shore from the amphibious objective area (AOA). The objective of this landing is assumed to be the establishment of a beachhead. The landing area (LA) is that part of the objective area within which landing operations are conducted. It includes the beach, the approaches to the beach, the transport areas, the fire support areas, the air occupied by close supporting aircraft, and the land included in the advance inland to the initial objective. This report will refer to the LA as the landing zone (LZ) and limit this zone to include the VSW/SZ/BZ, the landing lanes, craft landing site, and the bottom contact point (BCP). The BCP refers to that point at which an amphibious landing vehicle first touches the bottom (about 5-7 foot depth for a AAV). A schematic of the LZ is shown in Figure 2.

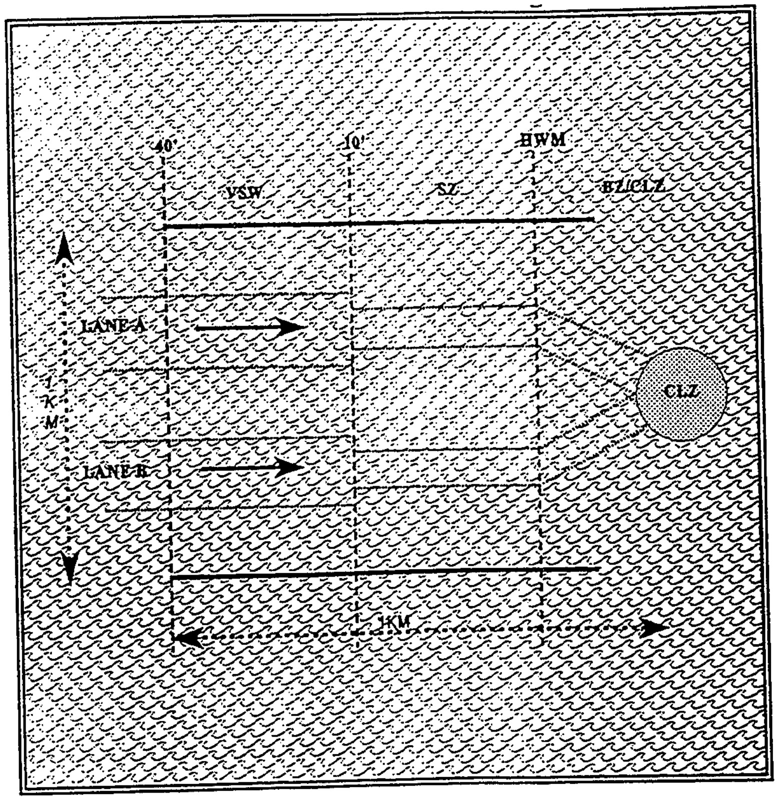

Figure 2. Schematic of Amphibious Landing Zone.

Landing lanes refer to both the boat lane and the actual landing lane. The boat lane has been modeled to be a 150 meter wide lane that extends through the VSW, up to, but not into, the SZ. The landing lane extends from the end of the boat lane, through the SZ/BZ, and terminates at the landing site, and has been modeled to be 50 meters wide. The LZ has been modeled to be contained within a 1 square kilometer region. [7]

It must be understood that the attacking force selects the landing site, not the defending force. However, since only certain coastal areas are conducive to an amphibious landing, the defending force can make tactical assumptions as to the location of a possible amphibious assault. Several factors contribute to the decision as to where to land the force. These factors include such considerations as access inland once ashore, landing site vulnerability to enemy fire, tidal conditions, weather patterns, coastal topography, and beach gradient. It is beach gradient which directly affects the work load on the MCM effort and the danger to the LF. Knowledge of the beach gradient is vitally important, because beach gradient is what determines the likelihood of enemy mines being present and provides the basis for estimates of mine densities in the VSW/SZ/BZ regions. For instance, a short, steep beach will not offer the defending force much room to lay mines, while a flat beach will allow for extensive mining. This research will assume a flat beach gradient, thereby affording the defending force the opportunity to lay a worst case density minefield. The tide is assumed to be low during the assault, thus further increasing LF exposure to mines on the beach. [8]

The Lemmings Scenario Commander Mine Warfare Group (CMWG) has decided to utilize Lemmings swarming vehicles as the only "in stride" breaching asset. Lemmings are assumed to be capable of command detonation or timed detonation in order to preserve their covert operation, although R&D of such a capability is still in its preliminary stages.

To land a typical Assault Echelon (AE), the Amphibious Task Force (ATF) has 30 Landing Craft Air Cushioned (LCAC) and 36 Amphibious Assault Vehicles (AAV). It is assumed that a force such as this will require 90 LCAC loads in order to deliver the required combat assets ashore. This assumption is based on the lift capacity of the LCAC and the force requirements needed ashore for a typical offensive amphibious operation, such as the one which was planned but never carried out during Desert Storm. This report will further break down the AE and will focus on a single Battalion Landing Team (BLT), using 10 LCACs and 13 AAVs to move the BLT ashore. The number of LCAC loads for one BLT is assumed to be 30 (one-third of the 90 needed by the entire AE). However, we further refines the AE by analyzing the landing of the BLT's 13 AAVs and only one round-trip of the 10 LCACs attached to the BLT, instead of the three round-trips that would actually be required. By focusing on this abridged BLT for modeling purposes, total force effects are not lost. Simple extrapolation can be used to see the effects on an entire AE. [8]

It is assumed that the AAV is capable of an OTH assault. The AAV7A1 manages only 8 knots at sea, and the combat effectiveness of the troops within begins to decline after only 30 minutes due to noise, fumes, heat, and motion. These deficiencies allow for a line of departure of only 2 nm from the beach, which is clearly not OTH. We assume that the AAV can conduct effective OTH assaults. This assumption is based on the capabilities of future assault craft, such as the Advanced Amphibious Assault Vehicle (AAAV).

The LF will make its approach in echelon and wedge formations, moving into columns just prior to entering the landing lanes. The AAVs will cross through the lanes ahead of the LCACs, moving through the littoral zones utilizing both lanes, and once ashore advance inland to clear the landing site for the LCACs. The LCACs will make their beach approach through lane A, off load their equipment at the landing site, and then depart for their return to the ATF through lane B.

8.3 Minefields, Mines, and Minefield Densities

8.3.1 Minefields and Employment Methods

Janus models five kinds of minefields: hand emplaced, ground vehicle emplaced, artillery emplaced, helicopter emplaced, and a manually operated portable minefield. Obviously, with Janus being designed to model ground combat, these "canned" minefields are specifically designed to simulate land minefields. As will become clear, it is possible to manipulate the databases of these five types of minefields so that one can transform one of these land minefields into an ocean/littoral minefield. The authors utilize the hand emplaced (HAND EMP), ground vehicle emplaced (MECH-1), and the helicopter emplaced (MECH-2) minefields. Due to the stochastic nature of Janus, each time a scenario is run, the placements of mines within the designated minefields are different from previous executions of the same scenario (i.e., mine location within minefields is random) [6].

A single HAND EMP minefield consists of 99 mines placed regularly in a 50 by 100 meter rectangle. The mines within this minefield are located in three strips of 33 mines each. The three strips are 15 meters apart and within a single strip, the mines are placed every 3 meters, alternately 3 meters to one side or the other of the strip. It should be noted that each time a scenario containing HAND EMP minefields is run, the placement of the mines along each of the three strips is random, only the spacing between the mines is a constant 3 meters. HAND EMP minefields are located and oriented by the user during initial planning (prior to execution of the scenario)[6].

MECH-1 emplaced minefields consist of mines that have a uniformly random distribution within each minefield. The length and width of MECH-1 minefields can be altered and set by the user. The user chooses either low (40 mines), medium (80 mines), or high (160 mines) density, positions, and then orients the minefields during initial planning. This type of minefield may be deployed either during initial planning or during the scenario execution phase [6].

Janus only allows for HAND EMP and MECH-1 minefields to be positioned during the initial planning phase of a given scenario. The remaining three types of minefields must be interactively laid by the user during the scenario execution phase. As a result, the MECH-2 minefields being utilized in this report must be interactively laid once scenario execution has occurred [6].

The MECH-2 minefield is emplaced by giving a helicopter a movement route over the minefield site and dropping the MECH-2 minefields at the desired location. The orientation of the minefield is that of the helicopter's flight path. The user decides through interface commands when to drop the minefields from the helicopter. The dimensions of the minefield can be altered by the user. The mines within MECH-2 minefields are randomly but uniformly distributed within the minefield dimensions. The densities are selected in an identical manner as that of the MECH-1 [6].

8.3.2 Mine Types

This research assumes the following mine types have been laid in the specified zones:

* Magnetic influence mines in the VSW
* Bottom contact mines in the SZ (5 to 10 feet depth)
* Anti-tank mines in the SZ (5 feet depth to HWM) and BZ

Of the five types of minefields, each can contain only one type of mine. There are 10 types of mines available in Janus, each type being defined by designated probabilities. It should be pointed out that one Janus minefield is not equivalent to the author's one square kilometer enemy minefield, through which the AE will cross. The enemy minefield is composed of a number of Janus minefields selected so that the enemy minefield densities and mine types are appropriate for each littoral zone.

We utilize three of the ten mine types available. As discussed earlier, one central aspect of the VSW/SZ/BZ mine threat is that adversaries intent upon denying U.S. and allied access to the beach will employ as many different types of mines as possible in the amphibious objective area (AOA), including influence mines in the VSW/SZ, anti-invasion and anti-tank mines in the SZ/BZ region. [8] As previously mentioned, we will assume magnetic influence mines in the VSW, bottom contact in the SZ, and anti-tank mines in the SZ/BZ region.

Janus mine type 1 will be designated as anti-tank mines and will be dispensed by the HAND EMP method in the SZ/BZ region. Janus mine type 2 will be designated as bottom contact mines and will be dispensed by the MECH-1 method in the SZ region. Finally, Janus mine type 3 will be designated as magnetic influence mines and will be dispensed by the MECH-2 method in the VSW region. Again, the mine types are defined by various probabilities which are appropriate for the mine type being modeled.

8.3.3 Densities

The minefield densities are assumed to be worst case:

* 500 mines per square kilometer in the VSW
* 1000 mines per square kilometer in the SZ
* 2000 mines per square kilometer in the BZ

The density assumption is directly linked to the flat beach gradient assumption and densities can be considered inversely proportional to depth. [8] Expected mine densities in the landing lanes were calculated using the worst case densities above and landing lane area per littoral zone. The results of the calculations indicate that 80 mines per lane can be expected, on average, for each scenario run, or 160 mines between the two landing lanes. Figure 3 is a schematic of the minefield densities.

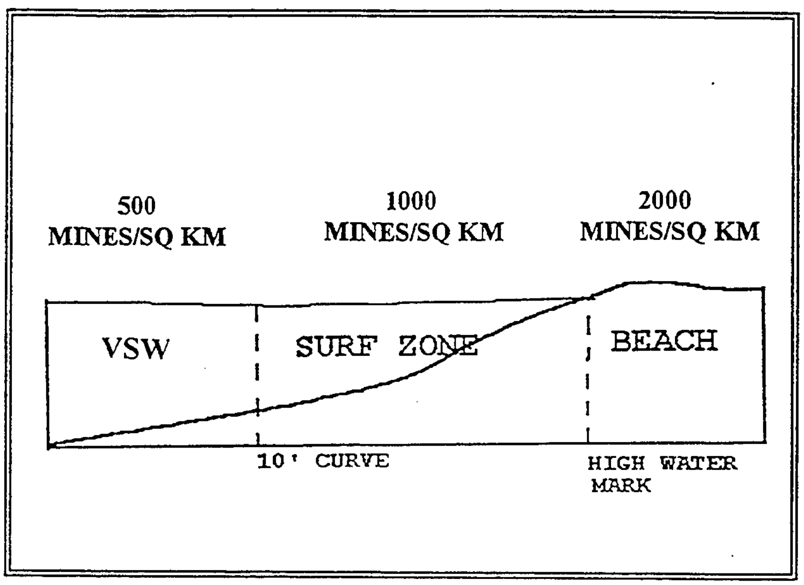

Figure 3 Beach Profile Showing Worst Case Mine Densities

8.4 Enemy Forces and Naval Gunfire Support (NGFS)

It is assumed that the amphibious landing will take place unopposed by enemy forces. This assumption was made in order to establish a clear base case comparison between MCM assets. Additionally, the amphibious landing has not been modeled to be covered by NGFS or air support. However, Janus allows for such modeling and any future studies of MCM assets and amphibious operations could incorporate such additions.

9 Scenario Development

Three scenarios have been created to examine Janus' ability to model diverse situations and its possible utility in evaluating the effects of new technologies. The scenarios described below examine the interactions between systems and mines (Bull Breaching), with current breaching capabilities (Traditional) and using a new technology (Lemmings).

9.1 Bull Breaching Scenario

The Bull Breaching Scenario simulates an amphibious landing through mined littoral zones without breaching operations being conducted prior to the assault. The intent of this scenario is to gauge the effect that heavily mined littoral zones would have on an amphibious assault being conducted with no breaching operations. The data generated from this scenario serves as a baseline for comparative analysis with the other scenarios of interest. The expectation is that the LF will experience significant losses on average during scenario execution. But, regardless of the results, the data generated will be used to gauge the relative effectiveness of both traditional and Lemming MCM methods employed in the other scenarios. Despite not utilizing any reasonable breaching method, the LF will nevertheless transit the littoral zones in the column formations previously discussed.

9.2 Traditional Scenario

The Traditional Scenario is an exact copy of the Bull Breaching scenario, except that prior to the assault, MF breaching is conducted in the VSW/SZ/BZ regions, attempting to clear the two landing lanes. As previously mentioned, traditional MCM assets being utilized for "in stride" breaching include the following:

* Four MH-53E Sea Dragon helicopters towing Mk 105 magnetic minesweeping hydrofoils to counter the magnetic mine threat in the VSW.
* Two Amphibious Assault Vehicles with Line Charges (AAVLCs).
* Four Amphibious Assault Vehicles with Mine Plows (AAVPs).

The sequence of this traditional "in stride"breaching operation is as follows: first, two Sea Dragons per lane sweep the VSW up to about the 8 to 10 foot depth, clearing the two 150 meter wide lanes in the VSW region; second, one AAVLC per lane fires its line charge at about the BCP (5 foot depth line), ideally breaching a 15 meter wide landing lane from the BCP to the landing site; and finally, two AAVPs per lane follow the AAVLC, commencing plowing operations at the BCP, and ideally proofing and widening to about 30 meters the landing lane up to the landing site. Once the lanes have been breached, or MCM assets killed, the remainder of the LF will proceed with the assault.

9.3 Lemming Scenario

As with the Traditional Scenario, the Lemmings Scenario is a copy of the Bull Breaching Scenario, except, of course, for the MCM method employed. This scenario utilizes one Lemmings swarm per lane, each swarm consisting of 130 Lemmings, to breach the two landing lanes. The size of each swarm was calculated using the estimated mine densities per lane and the 1.62 Lemming-to-mine ratio suggested by Foster-Miller.

The Lemming swarms are deployed by SEAL teams from 6 ZODIACs at the mouth of the landing lanes, at about the 40 foot depth curve. The deployment occurs just before dawn and about 90 minutes from H-hour, the time that the first vehicle reaches the landing site. This time frame enables the last of the BZ mines to be neutralized by Lemmings just as the first wave of the LF reaches the VSW.

10 Measures of Effectiveness (MOE)

Using the Janus Post Processor, data was collected and used to produce various MOEs. The goal is to see if sufficient battlefield information can be collected to give a user the necessary results of the system interactions. Four MOEs were investigated as typical, but many more could be examined. The results of MOE 1, combat power ashore is presented in Section 10.7 to give the reader a feel for possible analysis techniques evaluating the MOEs. Detailed results of the other MOE can be found in [5].

10.1 MOE 1

MOE 1, combat power ashore, is a critical indicator of the relative success of the "in stride" MCM operations conducted prior to the assault. MOE 1 is relevant to single scenario analysis and comparative analysis of all three scenarios.

10.2 MOE 2

MOE 2, landing force kills experienced during the assault, is also a critical indicator of the relative success of the "in stride" MCM operations conducted in each scenario. The analysis of MOE 2 is also relevant to each scenario and to a comparison between scenarios.

10.3 MOE 3

MOE 3, total MCM assets killed, applies specifically to the Traditional Scenario, and as such, is of little value for comparative analysis between scenarios. However, MOE 3 offers significant insight into the analysis of MOE 1 and MOE 2 with respect to the Traditional Scenario.

10.4 MOE 4

MOE 4, number of mines neutralized versus expected number of mines per landing lane, is relevant only to the Lemmings Scenario. The analysis of MOE 4 contributes to the analysis of MOE 1 and MOE 2 with respect to the Lemmings Scenario. It should be noted that the number of mines neutralized (killed) in the Lemmings Scenario is equal to the number of Lemmings killed.

10.5 Scenario Execution

A collection of color slides taken during the running of each scenario are contained in Appendix B. A brief description of each image is presented and they are listed in chronological order.

10.6 Data Collection and Analysis Concept

As a stochastic simulation, Janus produces output that is itself random, and must therefore be treated as only an estimate of the true characteristics of the model. The stochastic nature of Janus output makes comparing the three scenarios on the basis of only a single run of each a very unreliable approach to analysis. Consequently, 10 runs of each scenario were conducted in order to increase the accuracy and significance of the comparative analysis conducted on the different MCM methods.

Data collection is accomplished using the Janus Post Processing (PP) program. This program lets the user retrieve reports compiled from recording files made during a simulation run. There are ten PP reports available, ranging from an Artillery Impacts Report to Temperature and Work Load Profiles Report. The analysis for this report utilizes the Coroner's Report (CR) and the Minefields Report (MR). For each run of each scenario, these two reports were generated using the Janus PP program [6].

The CR provides a detailed account of each kill. Each row gives information about a single kill, and the rows are in chronological order. Information provided includes time of kill, kill type, name of unit killed, location of kill, and information on the killer [6].

The MR furnishes information about minefields and minefield encounters. The MR is divided into two sections, the first is the Minefield Summary Report (MSR) and the second is the Minefield Crossing Events Report (MCR). The MSR displays one row for each MF, providing information on the type of mine within the MF, the method for laying that MF, location and dimension of the MF, orientation angle, and density of the MF. The MCR displays the following information about units that encountered a given MF: time of encounter, name of unit crossing a MF, whether that unit is conducting breaching operations or not, entrance and exit points, and the MF number [6].

10.7 Graphical Results of MOE 1

Presented below is an example of the type of analysis the Janus combat model can provide. Raw data from scenario runs for this MOE can be found in Appendix C.

As representative of the possible analysis, the graph in Figure 4 compares average Combat Power Ashore (CPA) versus time between the three scenarios. The differences in CPA are obvious, with Bull Breaching realizing the least number of forces ashore and Lemmings realizing the greatest number. The last of the AAVs reaches the landing site around the 140 minute mark and the first LCAC reaches the beach around the 144 minute mark. Given this information, the Bull Breaching CPA curve is horizontal from about the 118 mark until the 132 mark, indicating that over a 14 minute period no forces (AAVs in this case) reached the beach. Similar lulls in CPA occur in the other scenarios around this same time frame, though not for as long. As it turns out, this time interval coincides with the time that the first AAVs are crossing through the SZ. The "gap" is the only zone which produces such distinct horizontal stretches in the CPA curves of all three scenarios. Graphical results for MOEs 2-4 can be found in [5].

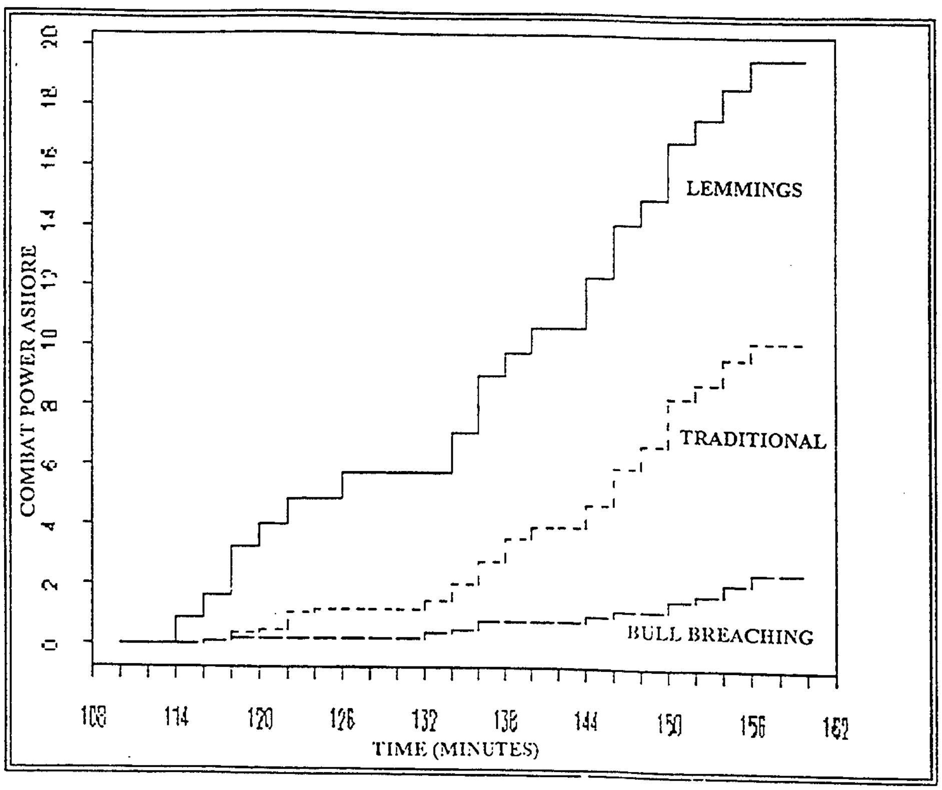

Figure 4. Comparing Average Combat Power Ashore Between Scenarios.

10.8 Conclusion

This research has shown the ability of a combat simulation to adequately portray systems in an amphibious operation. This required the modification of typically land based systems to realistically play in both the land and marine environment. Further extension of the model allowed the simulation of naval mines in the VSW/SZ and the capture of the interactions between systems and those mines. By the use of MOEs and data collected from Janus' Post Processor comparison of various scenarios were examined and found to produce results that pass the "common sense" test. It appears that high resolution modeling can give the combat developer useful results when working with the mine countermeasures problem. The model could then be used to specifically evaluate the added force benefits of new technologies such as Lemmings or be used to investigate optimal tactics to be used in amphibious operations.

11 Appendix A. Modeling System Probabilities

This appendix contains information on the percentage of reliability and survivability of each breaching asset, landing force mine activation and kill probabilities, and the dud probabilities of each mine type.

Each breaching asset is assigned a probability (reliability) that it will successfully neutralize each mine type it encounters, and a probability (survivability) that if it encounters a given mine type that it will survive that encounter. Reliability (R) and survivability (S) probabilities are contained in Table A1.

Breaching Assets Reliability/Survivability Probabilities			
Breaching Asset	Magnetic Influence (R/S)	Bottom Contact (R/S)	Anti-Tank (R/S)
Mk 105	95/90		
AAVLC		75/*	80/*
AAVP		75/75	90/75

Table A1. Reliability/Survivability Probabilities for Traditional Breaching Assets. The Star (*) represent the fact that once a line charge is expended, it cannot be reused. probabilities expressed as percentages.

Each landing force system (e.g., AAV, LCAC) is assigned a probability (activation) that it will activate a given mine type if such a mine is encountered, and a probability (kill) that if activation occurs will that unit be killed. Activation (A) and kill (K) probabilities for landing force systems are contained in Table A2.

Mine Activation and Kill Probabilities			
Landing Force System	Magnetic Influence (A/K)	Bottom Contact (A/K)	Anti-Tank (A/K)
AAV	85/75	80/75*	90/85*
LCAC	75/30	10/40	20/50

Table A2. Mine Activation and Kill Probabilities. The Star(*) indicates percentage based on track hitting the mine. probabilities expressed as percentages.

Finally, Table A3 contains the probability that each mine type will fail to activate if encountered by a breaching asset or landing force system (dud probability).

Mine Type	Mine Dud Probability
Magnetic Influence	.04
Bottom Contact	.04
Anti-tank	.03

Table A3. Mine Dud Probabilities.

12 Appendix B. Scenario Images

Selected images copied from actual runs of the Janus scenarios are contained in this appendix. The figures are arranged in chronological order, with general setup images presented first, followed by Bull Breaching images, Traditional images, and finally Lemmings images. A brief explanation of each image is included below.

General scenario images:

Figure B1. Full view of the landing zone and littoral regions. The coast appears as a brown line.

Figure B2. Red force helicopter laying magnetic mines in the VSW.
Bull Breaching Scenario.

Figure B3. The AAV approach formation at about 15 nm off-shore with movement routes shown.

Figure B4. The AAVs moving into column formation to cross through the MF and the LCAC wave approaching at about 15 nm.

Figure B5. LCACs crossing MF following the loss of 13 of 13 AAVs.

Figure B6. The "lone" LCAC after the loss of 9 of 10 LCACs.
Traditional Scenario.

Figure B7. AAVs commencing their assault through breached landing lanes. Breached areas are indicated by yellow lanes.

Figure B8. LCACs crossing MF following the loss of 3 of 13 AAVs.

Figure B9. Two of 10 LCACs were killed crossing the MF.
Lemmings Scenario.

Figure B10. Movement routes of ZODIACs to the Lemmings drop point at the mouth of each landing lane.

Figure B11. Lemmings just after deployment each Lemming symbol represents 43 individual Lemmings, thus making up two swarms of 129 Lemmings.

Figure B12. Twenty-eight Lemmings were killed, which indicates that 28 mines were neutralized.

Figure B13. Zero AAVs were killed.

Figure B14. Zero LCACs were killed.

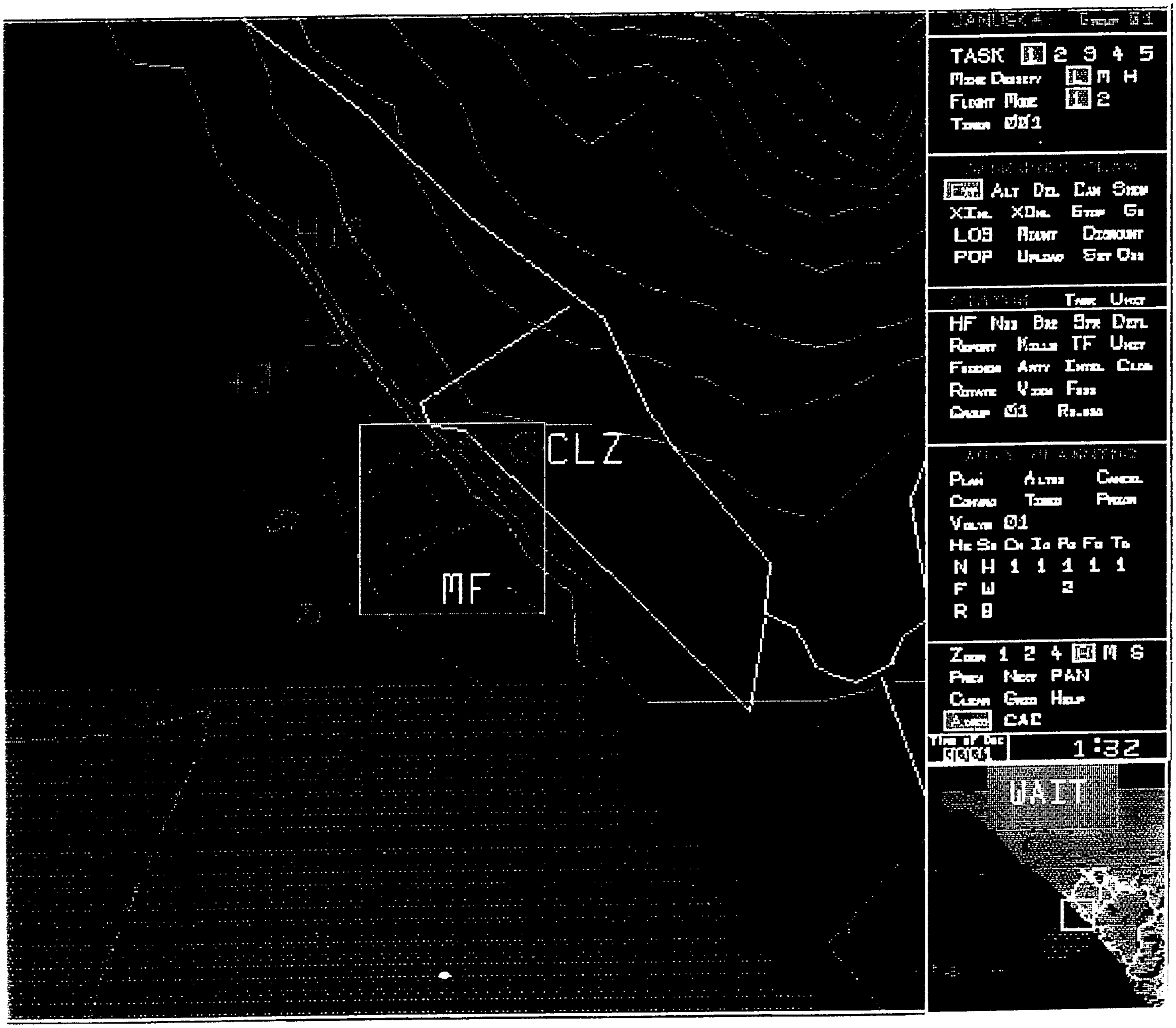

Figure B1. Full view of the landing zone and littoral regions. The coast appears as a brown line.

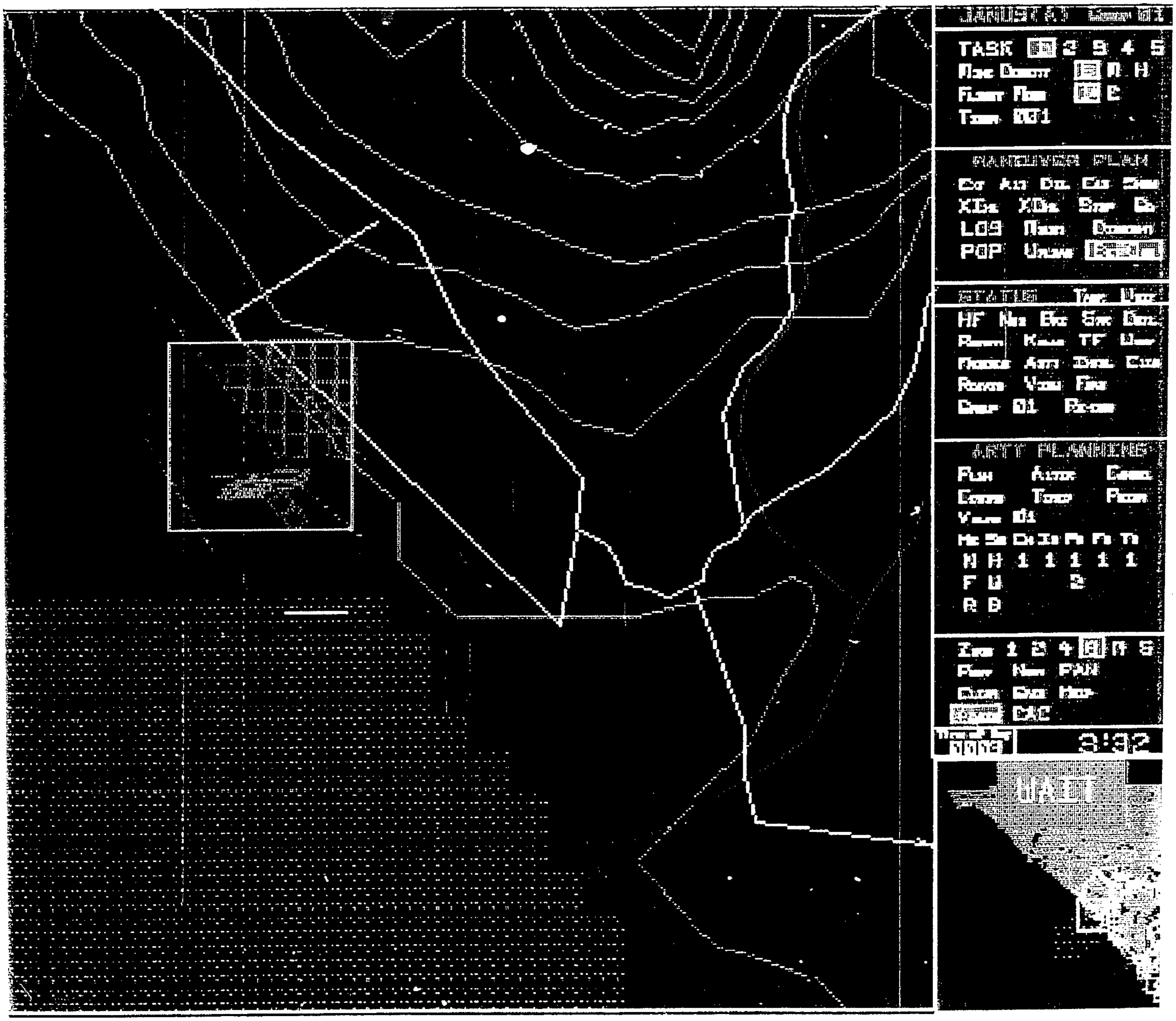

Figure B2. Red force helicopter laying magnetic mines in the VSW.

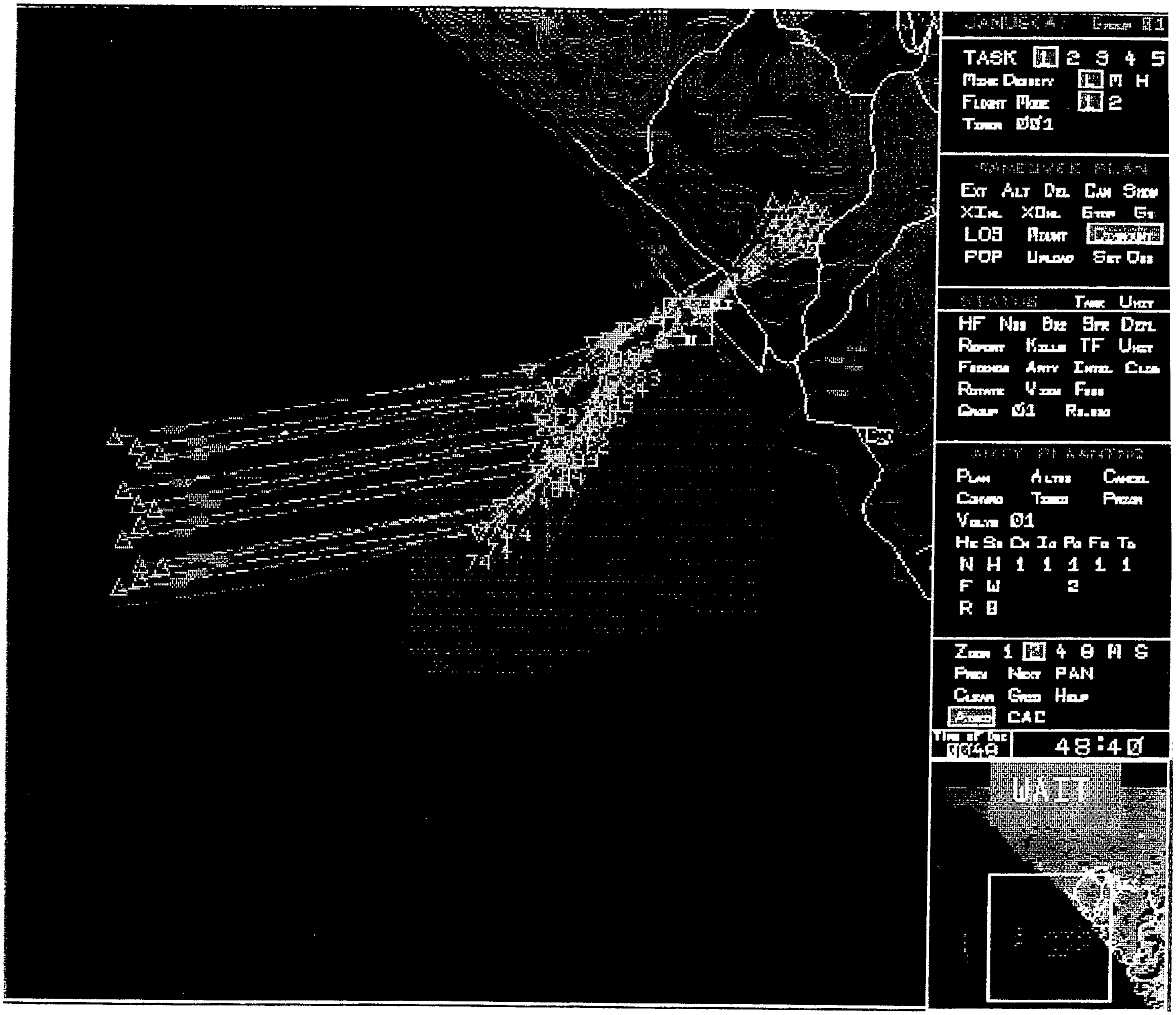

Figure B3. The AAV approach formation at about 15nm off-shore with movement routes shown.

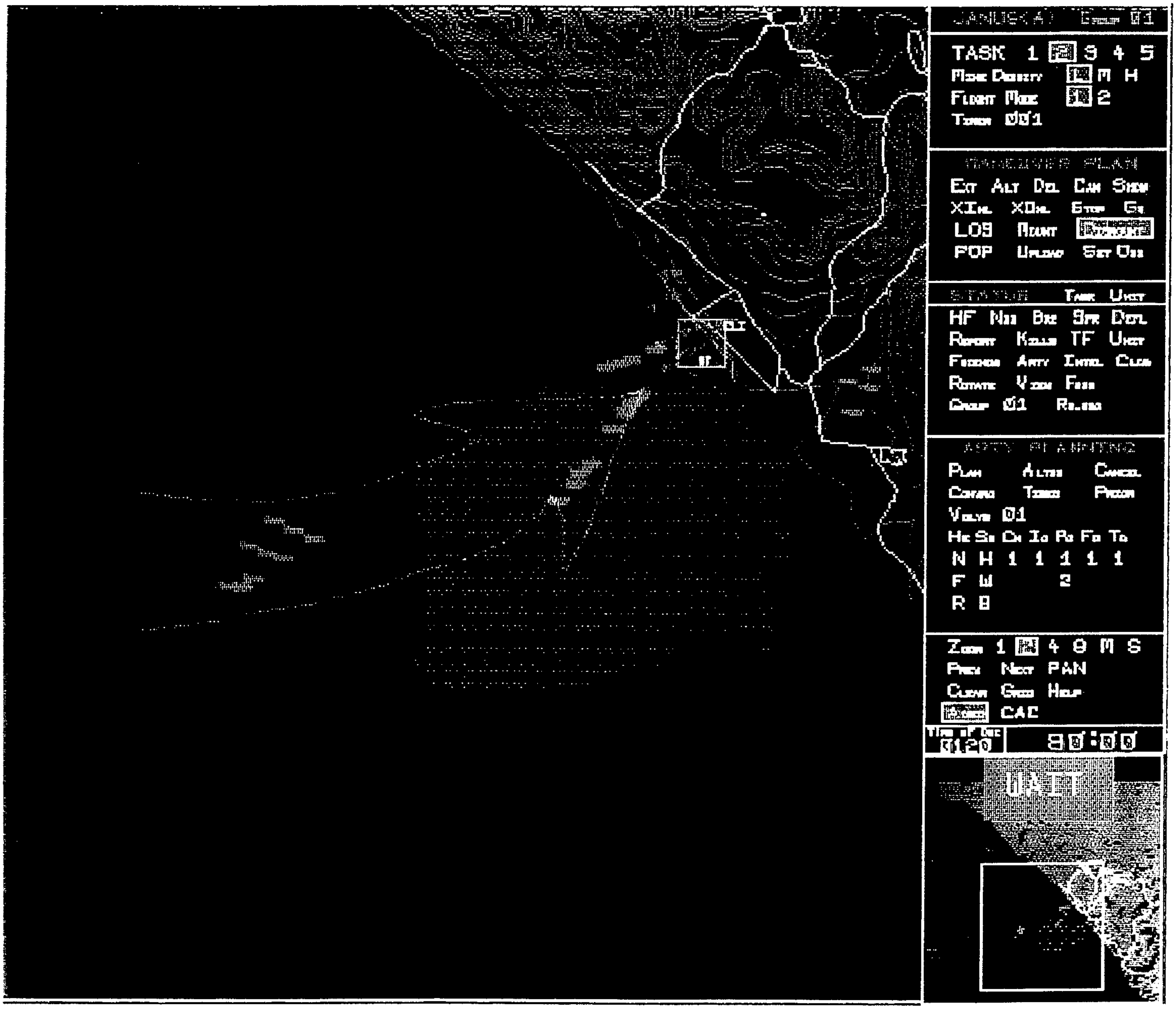

Figure B4. The AAVs moving into column formation to cross through the MF and the LCAC wave approaching at about 15nm.

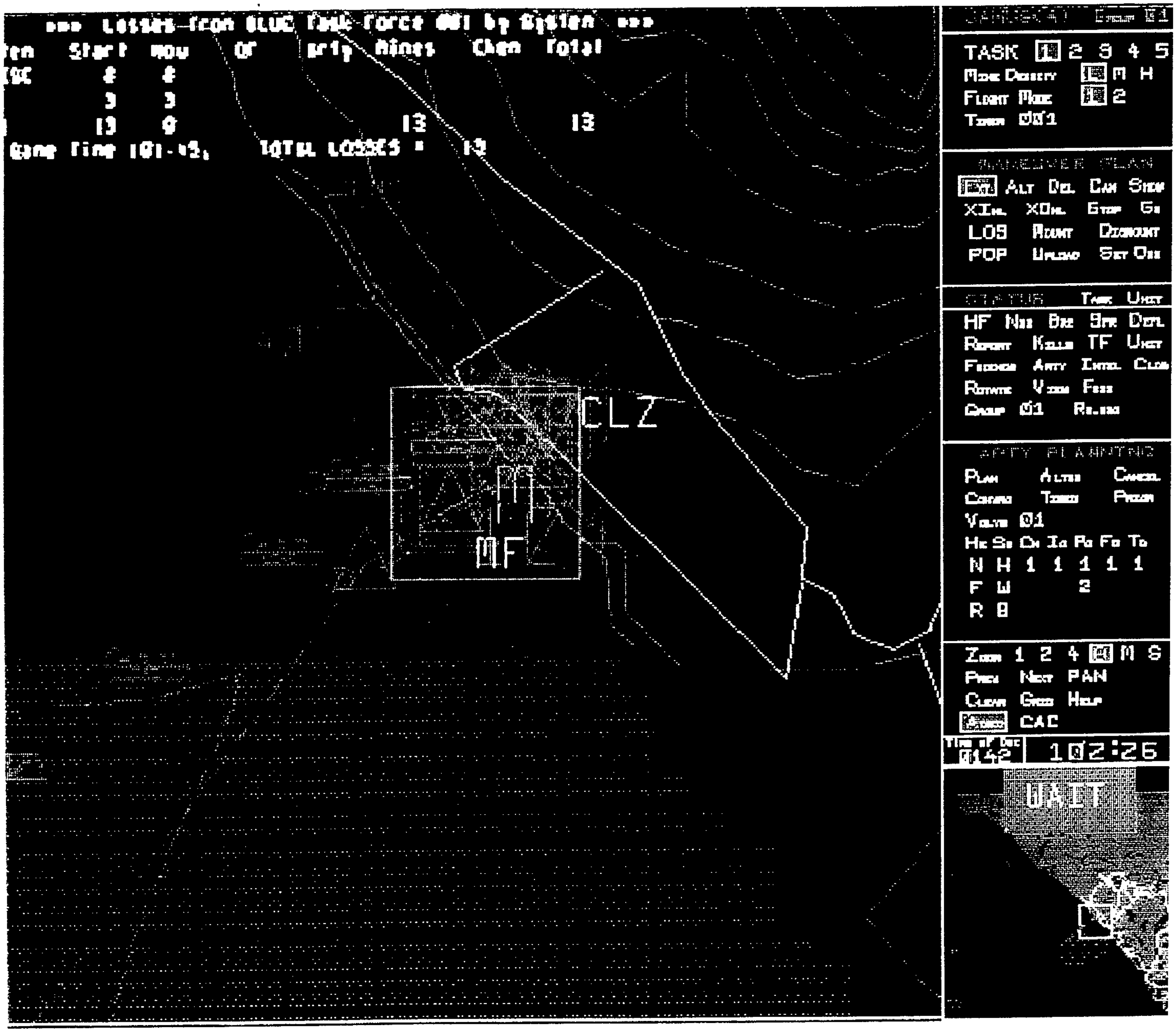

Figure B5. LCACs crossing MF following the loss of 13 of 13 AAVs.

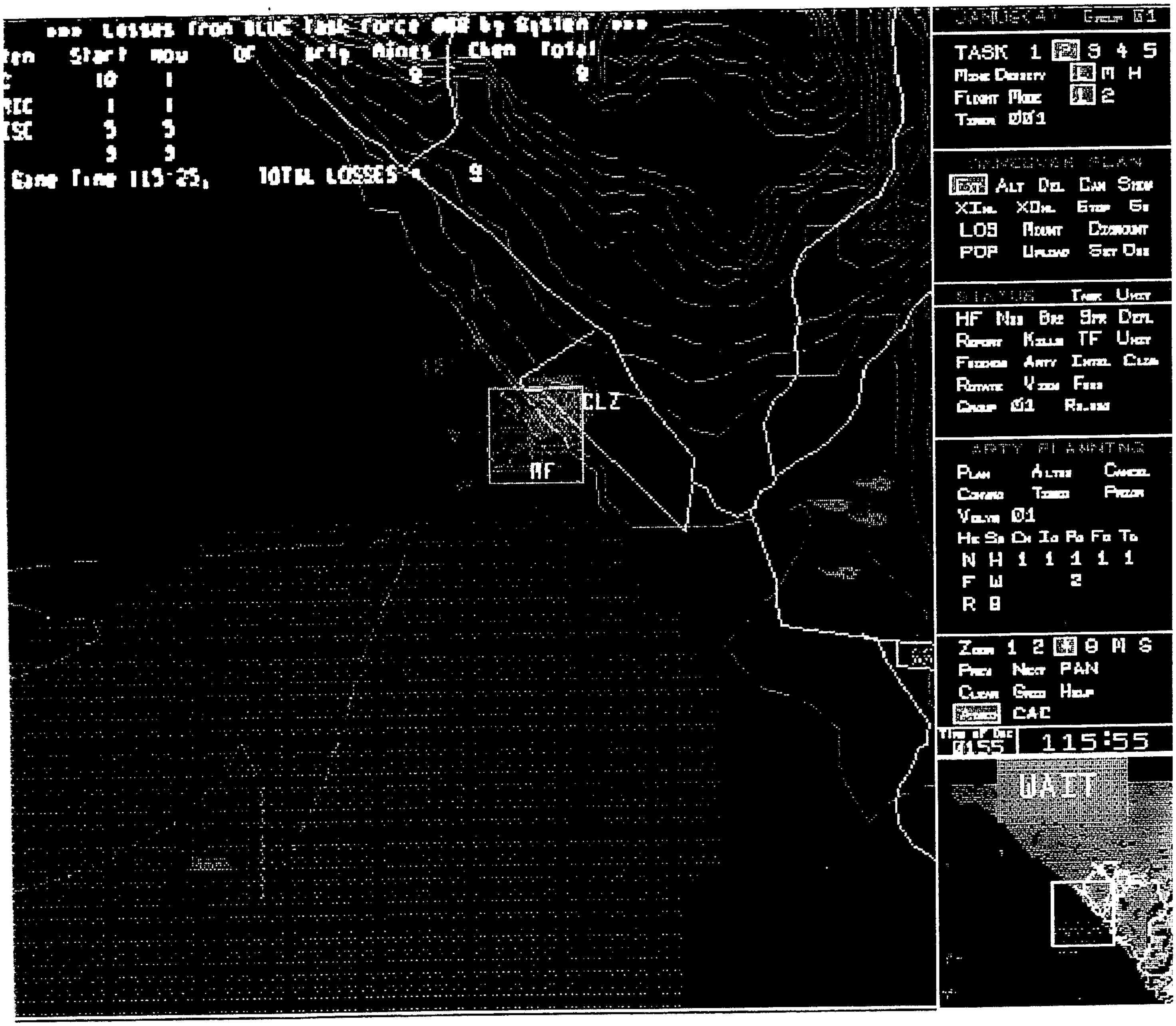

Figure B6. The "lone" LCAC after the loss of 9 of 10 LCACs.

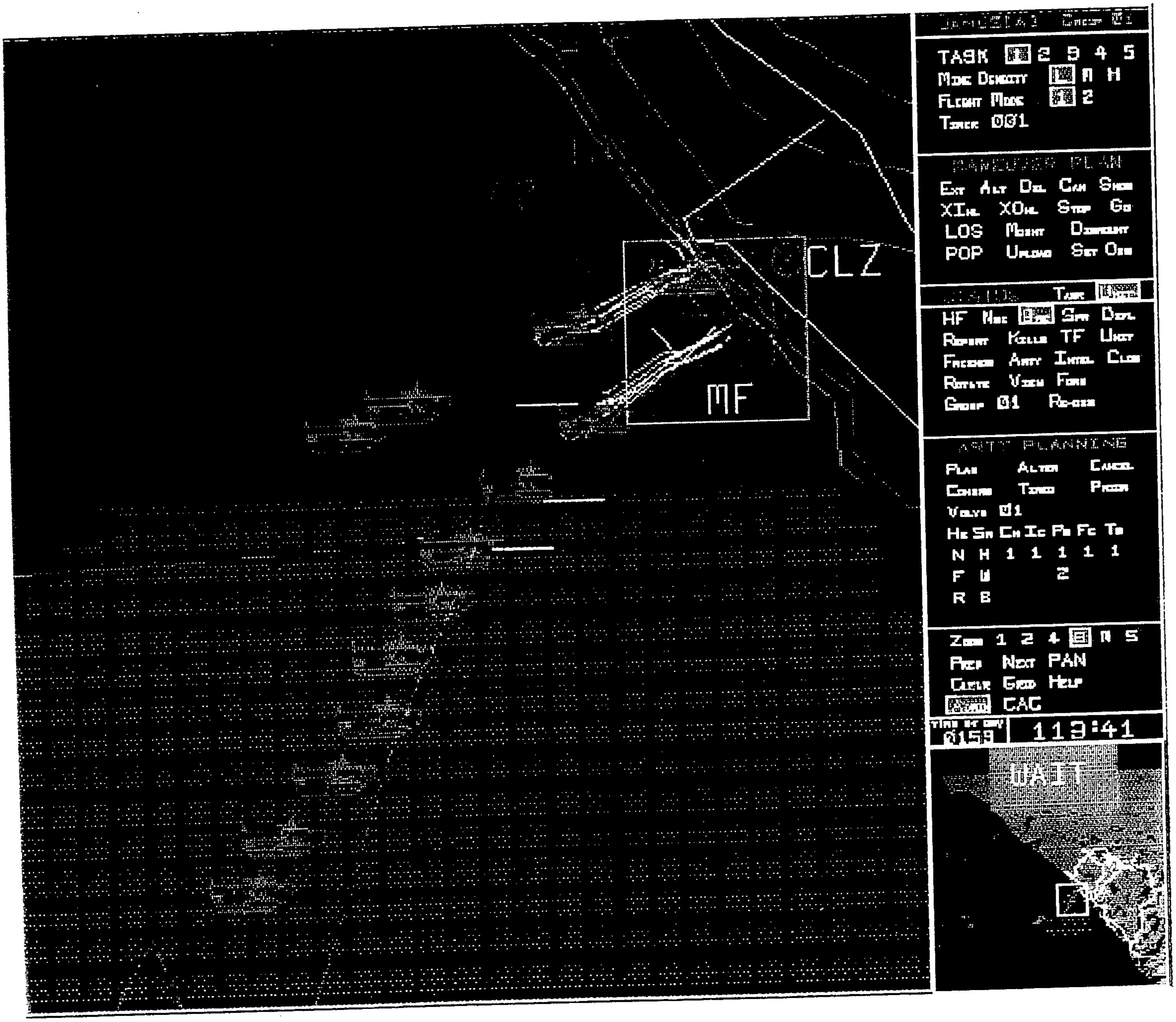

Figure B7. AAVs commencing their assault through breached landing lanes. Breached areas are indicated by yellow lanes.

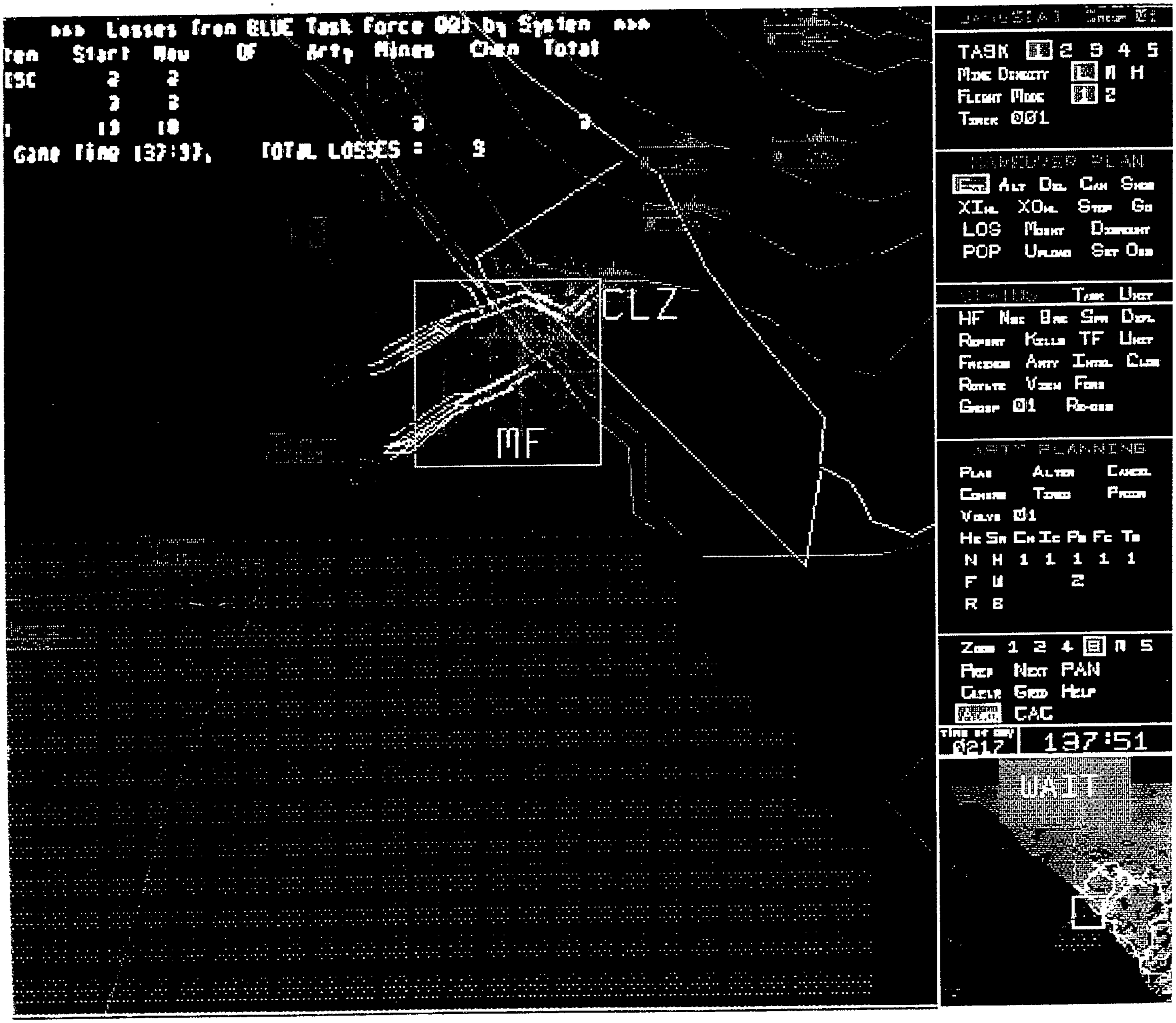

Figure B8. LCACs crossing MF following the loss of 3 of 13 AAVs.

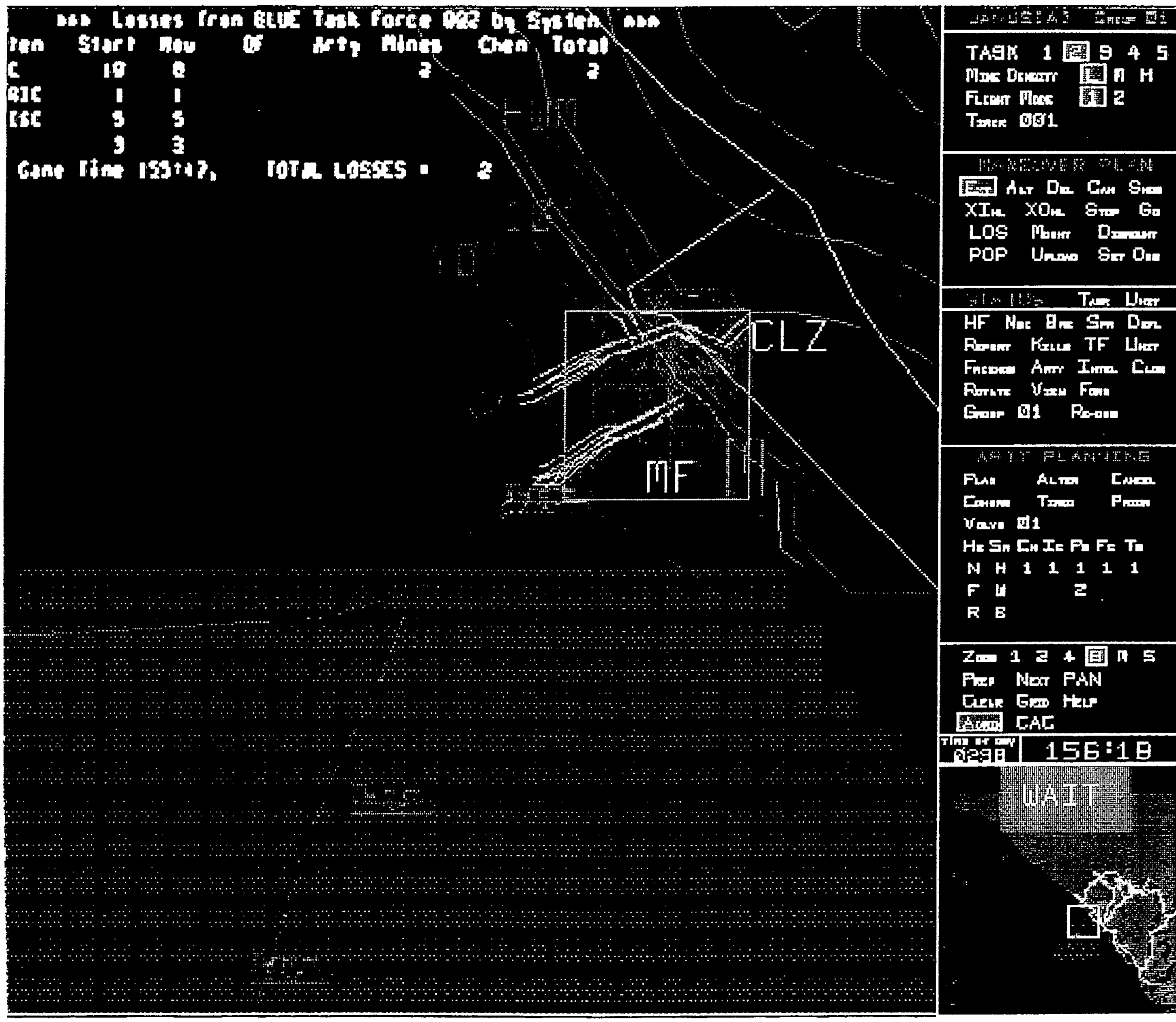

Figure B9. Two of 10 LCACs were killed crossing the MF.

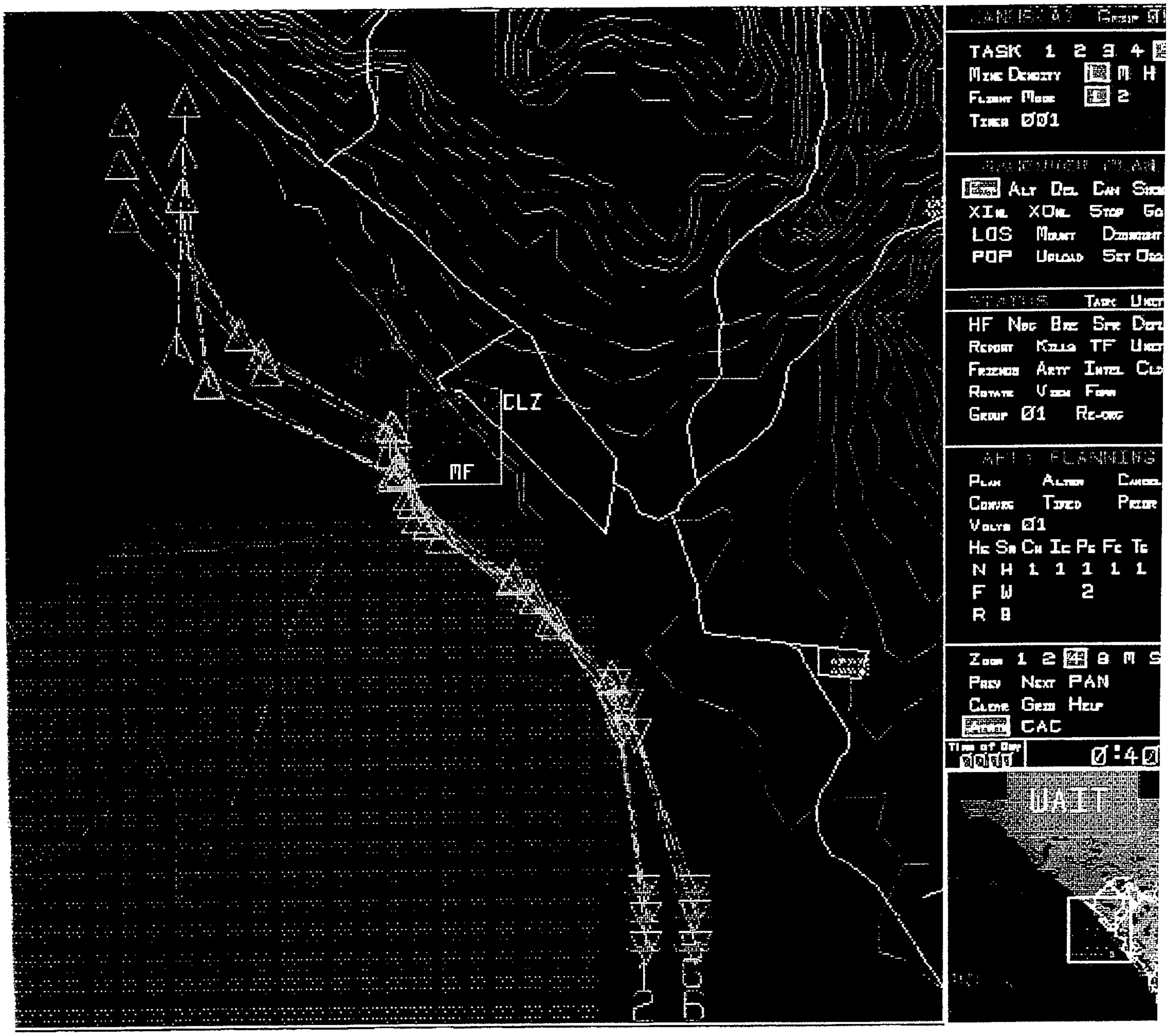

Figure B10. Movement routes of ZODIACs to the Lemmings drop point at the mouth of each landing lane.

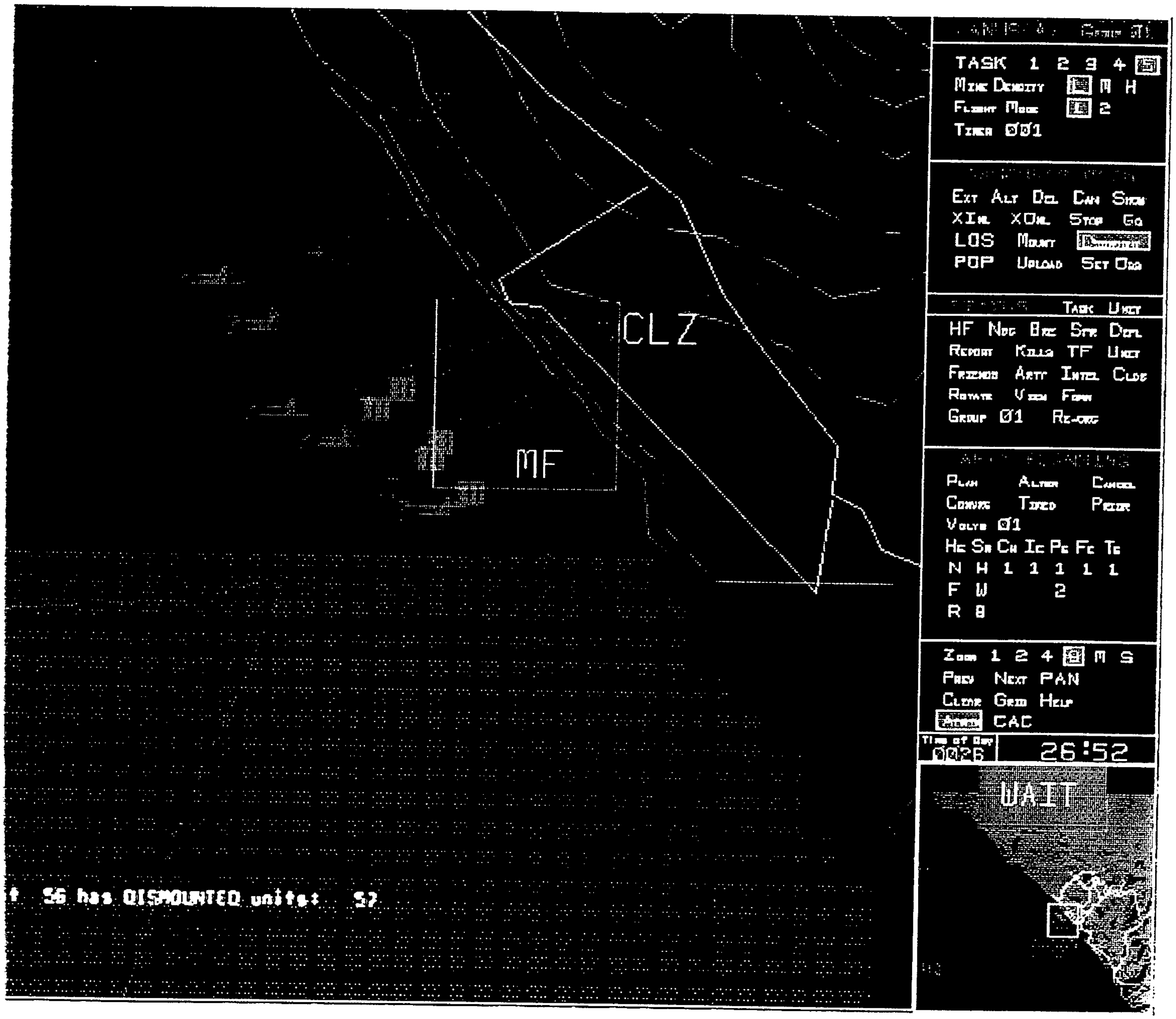

Figure B11. Lemmings just after deployment. Each Lemming symbol represents 43 individual Lemmings, thus making up two swarms of 129 Lemmings.

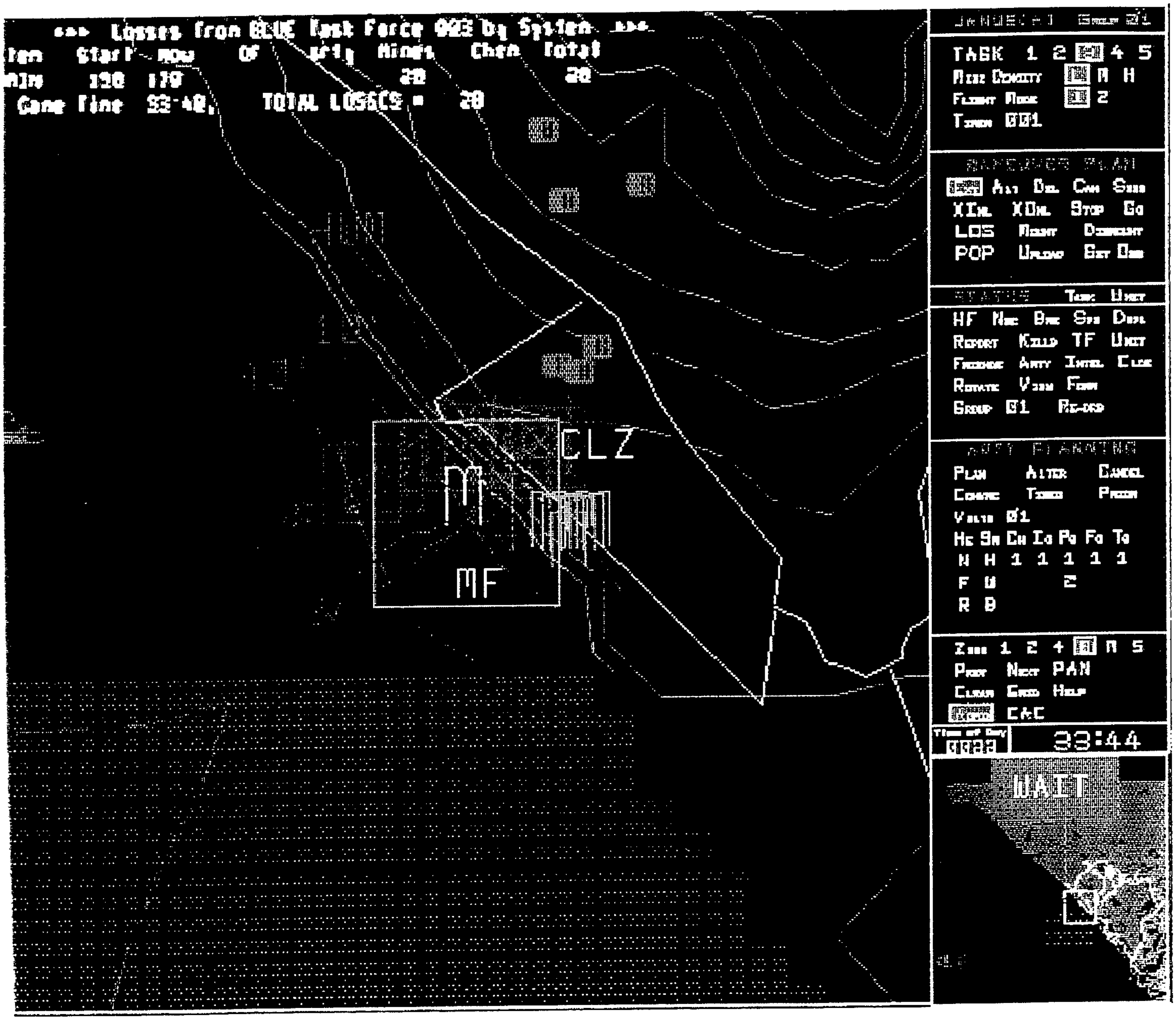

Figure B12. Twenty-eight Lemmings were killed, which indicates that 28 mines were neutralized.

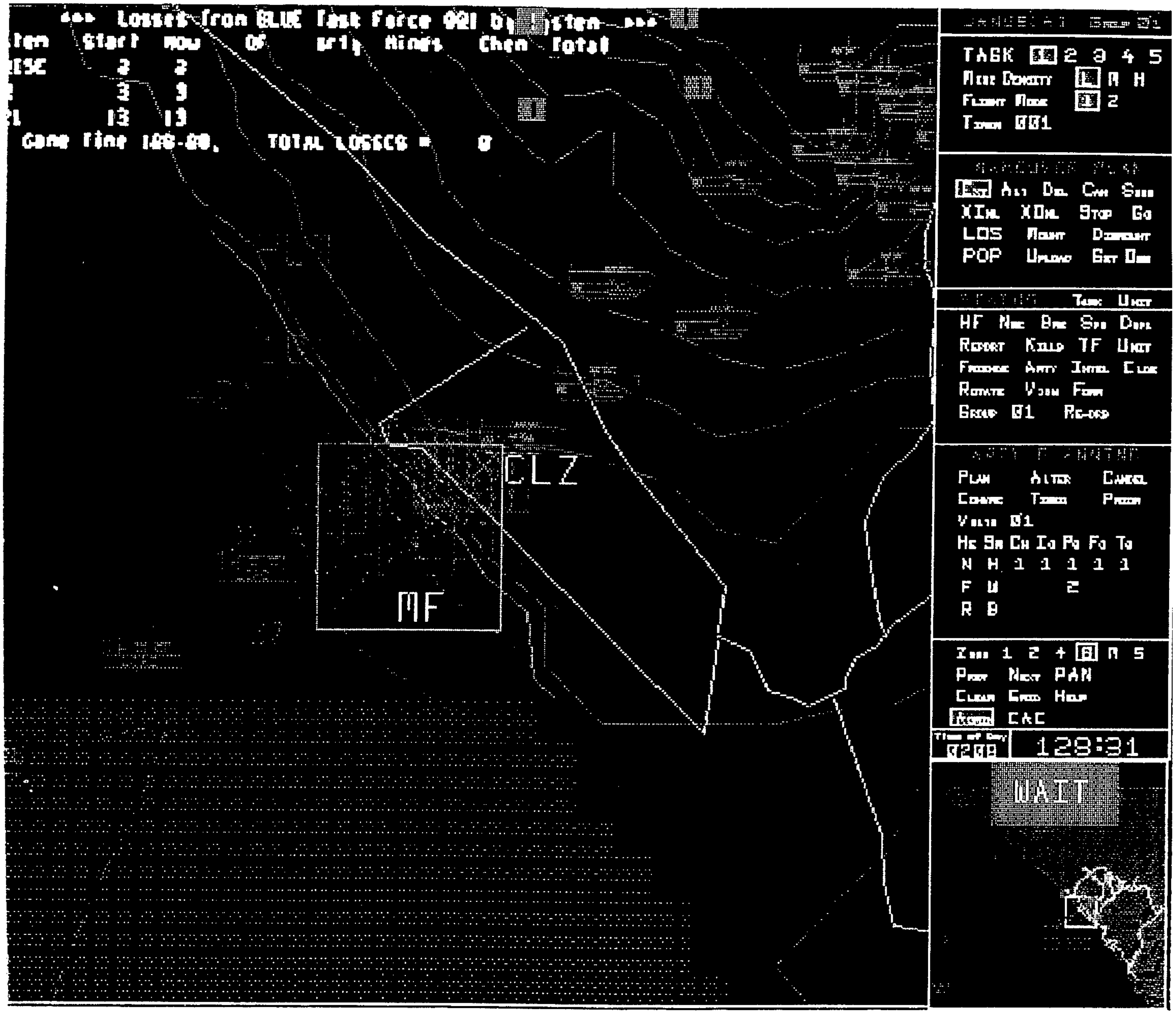

Figure B13. Zero AAVs were killed.

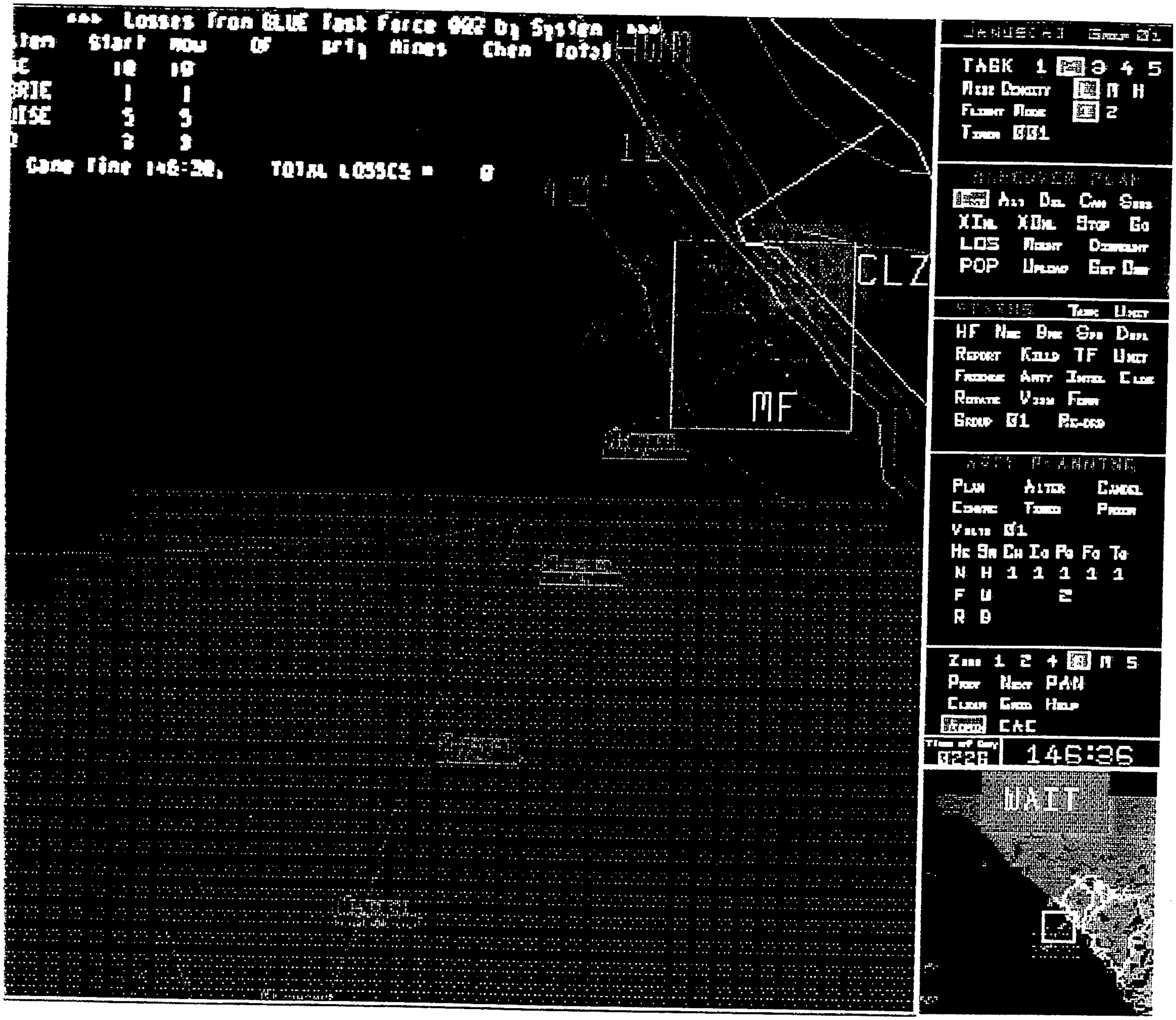

Figure B14. Zero LCACs were killed.

13 Appendix C. Data from Scenario Runs

Tables C1, C2, and C3 show the simulation results for ten runs of each scenario (Bull Breaching, Traditional, and Lemmings, respectively). The last row provides the averaged values. Combat Power Ashore is measured by counting the number of combat vehicles that reach the Craft Landing Zone over 5 minute time windows.

COMBAT POWER ASHORE; BULL BREACHING SCENARIO												
RUN NUMBER	SCENARIO TIME (MINUTES) 110	115	120	125	130	135	140	145	150	155	160	TOTAL ASHORE
RUN 1	0	0	0	0	0	0	0	0	0	0	0	0
RUN 2	0	0	0	0	1	0	0	1	2	0	0	4
RUN 3	0	0	0	0	0	1	0	0	1	0	0	2
RUN 4	0	1	0	0	0	0	2	0	1	0	0	4
RUN 5	0	0	0	0	0	0	0	0	0	0	0	0
RUN 6	0	0	0	0	0	1	0	0	2	0	0	3
RUN 7	0	0	0	0	0	0	1	3	1	0	0	5
RUN 8	0	1	0	0	2	0	0	0	1	0	0	4
RUN 9	0	0	0	0	1	0	0	0	1	0	0	2
RUN 10	0	0	0	0	0	0	0	0	1	0	0	1
AVERAGE	0	0.2	0	0	0.4	0.2	0.3	0.4	1.0	0	0	2.5

Table C1. Combat Power Ashore as a Function of Time, Bull Breaching scenario.

COMBAT POWER ASHORE; TRADITIONAL SCENARIO												
RUN NUMBER	SCENARIO TIME (MINUTES)											TOTAL ASHORE
	110	115	120	125	130	135	140	145	150	155	160	
RUN 1	0	0	0	0	0	0	0	4	1	0	0	5
RUN 2	0	0	2	0	1	1	2	4	3	0	0	13
RUN 3	0	0	2	0	4	2	3	4	3	0	0	18
RUN 4	0	0	0	0	0	2	3	2	2	0	0	9
RUN 5	0	0	0	0	0	1	1	3	2	0	0	7
RUN 6	0	2	0	0	0	2	2	3	3	0	0	12
RUN 7	0	1	0	0	1	2	1	4	3	0	0	12
RUN 8	0	1	1	0	0	1	0	2	1	0	0	6
RUN 9	0	1	2	0	4	2	2	4	1	0	0	16
RUN 10	0	0	0	0	2	2	0	0	0	0	0	4
AVERAGE	0	0.5	0.7	0	1.2	1.5	1.4	3.0	1.9	0	0	10.2

Table C2. Combat Power Ashore as a Function of Time, Traditional Scenario.

COMBAT POWER ASHORE; LEMMINGS SCENARIO												
RUN NUMBER	SCENARIO TIME (MINUTES)											TOTAL ASHORE
	110	115	120	125	130	135	140	145	150	155	160	
RUN 1	1	3	1	1	2	2	3	4	3	0	0	20
RUN 2	1	3	1	1	2	3	3	3	3	0	0	20
RUN 3	1	3	1	1	3	3	3	4	3	0	0	22
RUN 4	1	4	0	0	2	2	2	3	2	0	0	16
RUN 5	1	4	1	1	3	3	2	4	3	0	0	22
RUN 6	1	4	1	1	1	3	3	3	3	0	0	20
RUN 7	1	3	1	1	3	3	3	3	3	0	0	21
RUN 8	1	2	1	0	2	3	3	4	3	0	0	19
RUN 9	0	3	1	1	2	2	3	4	3	0	0	19
RUN 10	1	2	1	1	2	3	1	4	2	0	0	17
AVERAGE	0.9	3.1	0.9	0.8	2.2	2.7	2.6	3.6	2.8	0	0	19.6

Table C3. Combat Power Ashore as a Function of Time, Lemmings Scenario.

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